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Title of invention

"A method for transmitting images, and an image coder"
(Menetelmä kuvien lähettämiseksi ja kuvakooderi)

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A method for transmitting images, and an image coder

The present invention relates to a method for transmitting images according to the preamble of the claim 1. The present invention also relates to a device for transmitting frames according to the preamble of the claim 12. The present invention relates furthermore to an encoder according to the preamble of the claim 23, to a decoder according to the preamble of the claim 24 to a codec according to the preamble of the claim 25, to a mobile terminal according to the preamble of the claim 26, and a storage media for storing a software program according to the preamble of the claim 27.

The image can be any digital image, a video image, a TV image, an image generated by a video recorder, a computer animation, a still image, etc. One image consists of pixels which are arranged in horizontal and vertical lines, and the number of which in one image is typically tens of thousands. In addition, the information generated for each pixel contains, for instance, luminance information about the pixel, typically with a resolution of eight bits, and in colour applications also chrominance information, e.g. a chrominance signal. This chrominance signal further consists of two components, Cb and Cr, which are both typically transmitted with a resolution of eight bits. On the basis of these luminance and chrominance values, it is possible at the receiving end to form information corresponding to the original pixel on the display device of a video terminal. In said example, the quantity of data to be transmitted for each pixel is 24 bits uncompressed. Thus, the total amount of information for one image amounts to several megabits. In the transmission of a moving image, several images are transmitted per second, for instance in a TV image, 25 images are transmitted per second. Without compression, the quantity of information to be transmitted would amount to tens of megabits per second. However, for example in the Internet data network, the data transmission rate can be in the order of 64 kbits per second, which makes uncompressed real time image transmission via this network practically impossible.

To reduce the amount of information to be transmitted, different compression methods have been developed, such as the JPEG, MPEG and H.263 standards. In the transmission of video, image compression

can be performed either as inter-frame compression, intra-frame compression, or a combination of these. In inter-frame compression, the aim is to eliminate redundant information in successive image frames. Typically, images contain a large amount of non-varying information, for example a motionless background, or slowly changing information, for example when the subject moves slowly. In inter-frame compression, it is also possible to utilize motion compensated prediction, wherein the aim is to detect elements in the image which are moving, wherein a motion vector and some kind of prediction error information relating to of this entity are transmitted instead of transmitting the pixel values representing the whole entity. Thus, the direction of the motion and the speed of the subject in question is defined, to establish this motion vector. To enable the use of image compression techniques, the transmitting and the receiving video terminal are required to have such a high processing speed that it is possible to perform compression and decompression in real time.

In several image compression techniques, an image signal converted into digital format is subjected to a discrete cosine transform (DCT) before the image signal is transmitted to a transmission path or stored in a storage means. Using a DCT, it is possible to calculate the frequency spectrum of a periodic signal, i.e. to perform a transformation from the time domain to the frequency domain. In this context, the word discrete indicates that separate pixels instead of continuous functions are processed in the transformation. In a digital image signal, neighbouring pixels typically have a substantial spatial correlation. One feature of the DCT is that the coefficients established as a result of the DCT are practically uncorrelated; hence, the DCT conducts the transformation of the image signal from the time domain to the frequency domain in an efficient manner, reducing the redundancy of the image data. As such, use of transform coding is an effective way of reducing redundancy in both inter-fram and intra-frame coding.

Current block-based coding methods used in still image coding and video coding for independently coded key frames (intra-frames) use a block-based approach. In general, an image is divided into NxM blocks that are coded independently using some kind of transform coding. Pure block-based coding only reduces the interpixel correlation within

one block, without considering the interblock correlation of pixels. Therefore, pure block-based coding produces rather high bit rates even when using transform-based coding, such as DCT, which has very efficient energy packing properties for highly correlated data. Therefore, current digital image coding standards exploit certain methods that also reduce the correlation of pixel values between blocks.

Current digital image coding methods perform prediction in the transform domain, i.e. they try to predict the DCT coefficients of a block currently being coded using the previous coded blocks and are thus coupled with the compression method. Typically a DCT coefficient that corresponds to the average pixel value within an image block is predicted using the same DCT coefficient from the previous coded block. The difference between the actual and predicted coefficient is sent to decoder. However, this scheme can predict only the average pixel value, and it is not very efficient.

Prediction of DCT coefficients can also be performed using spatially neighbouring blocks. For example, a DCT coefficient that corresponds to the average pixel value within a block is predicted using the DCT coefficient(s) from a block to the left or above the current block being coded. DCT coefficients that correspond to horizontal frequencies (i.e. vertical edges) can be predicted from the block above the current block and coefficients that correspond to vertical frequencies (i.e. horizontal edges) can be predicted from the block situated to the left. Similar to the previous method, differences between the actual and predicted coefficients are coded and sent to the decoder. This approach allows prediction of horizontal and vertical edges that run through several blocks.

In MPEG-2 compression, the DCT is performed in blocks so that the block size is 8×8 pixels. The luminance level is transformed using full spatial resolution. Both chrominance signals are subsampled, for example a field of 16×16 pixels is subsampled into a field of 8×8 pixels. The differences in the block sizes are primarily due to the fact that the eye does not discern changes in chrominance equally well as changes in luminance, wherein a field of 2×2 pixels is encoded with the same chrominance value.

The MPEG-2 standard defines three frame types: an I-frame (Intra), a P-frame (Predicted), and a B-frame (Bidirectional). The I-frame is generated solely on the basis of information contained in the image itself, wherein at the receiving end, this I-frame can be used to form the entire image. The P-frame is formed on the basis of the closest preceding I-frame or P-frame, wherein at the receiving stage the preceding I-frame or P-frame is correspondingly used together with the received P-frame. In the composition of P-frames, for instance motion compensation is used to compress the quantity of information. B-frames are formed on the basis of the preceding I-frame and the following P- or I-frame. Correspondingly, at the receiving stage it is not possible to compose the B-frame until the preceding and following frames have been received. Furthermore, at the transmission stage the order of these P- and B-frames is changed, wherein the P-frame following the B-frame is received first. This tends to accelerate reconstruction of the image in the receiver.

Intra-frame coding schemes used in prior art solutions are inefficient, wherein transmission of intra-coded frames is bandwidth-exessive. This limits the usage of independently coded key frames in low bit rate digital image coding applications.

The system in this invention addresses the problem of how to further reduce redundant information in image data and to produce more efficient coding of image data by introducing a spatial prediction scheme involving the prediction of pixel values, that offers possibility for prediction from several directions. This allows efficient prediction of edges with different orientations, resulting in considerable savings in bit rate. The system also uses context-dependent selection of suitable prediction methods, which gives further savings in bit rate.

The present invention describes a method to perform spatial prediction of pixel values within an image. The technical description of this document introduces a system for spatial prediction that can be used for block-based still image coding and for intra-frame coding in block-based video coders. The key elements of the invention are the use of multiple prediction methods and the context-dependent selection and

signaling of the selected prediction method. The use of multiple prediction methods and the context-dependent selection and signaling of the prediction methods allow substantial savings in bit rate to be achieved compared with prior art solutions.

It is the object of the present invention to improve encoding and decoding of digital image such that higher encoding efficiency can be achieved and the bit rate of the encoded digital image can be further reduced.

According to the present invention, this object is achieved by an encoder for performing spatially predicted encoding of image data. The present invention is primarily characterized in what is presented in the characterizing part of claim 1. The device for transmitting frames according to the present invention is primarily characterized in what is presented in the characterizing part of claim 12. The encoder according to the present invention is primarily characterized in what is presented in the characterizing part of claim 23. The decoder according to the present invention is primarily characterized in what is presented in the characterizing part of claim 24. The codec according to the present invention is primarily characterized in what is presented in the characterizing part of claim 25. The mobile terminal according to the present invention is primarily characterized in what is presented in the characterizing part of claim 26. The storage media for storing a software program according to the present invention is primarily characterized in what is presented in the characterizing part of claim 27. The invention is based on the idea that to perform spatial prediction of pixel values for a block to be coded, the adjacent, decoded blocks are examined to find if there exists some directionality in the contents of the adjacent blocks. This directionality information is then used to classify those blocks. Based on the combination of the classes of the adjacent blocks the contents (pixel values) of the current block is then predicted using a suitable prediction method. The prediction method is then signalled to the decoder. Prediction error information is also sent if it is efficient to do that in a distortion vs. bit-rate sense.

Considerable advantages are achieved with the present invention when compared with solutions of prior art. Using a method according to the

invention, it is possible to reduce the amount of information needed when transmitting images in digital format.

In general, the method according to the invention can be applied to block-based still image coding as well as to intra-frame coding in a block-based digital image coder.

In the following, the invention will be described in more detail with reference to the appended figures, in which

Fig. 1 shows the structure of a digital image transmission system,

Fig. 2 shows the spatial prediction method of the present invention as a block diagram,

Figs. 3a—3c show an illustration of blocks that are used for prediction according to an advantageous embodiment of the present invention,

Fig. 4 shows the mapping of directionality classes to context classes according to an advantageous embodiment of the present invention,

Figs. 5a—5p show an illustration of pixels that are used for prediction according to an advantageous embodiment of the present invention,

Fig. 6 shows an advantageous bitstream syntax of the displacement information transmission, and

Fig. 7 is a schematic representation of a portable teleconferencing device implementing a method according to the invention.

The intra-frame prediction method described in this invention works in a block-based manner and can be applied to image frames that comprise NxM blocks scanned *e.g.* row by row from left to right and from top to bottom. It is obvious that other scanning directions can also be used in connection with the present invention. Spatial prediction is performed

for each intra-coded block using previously reconstructed blocks in the same frame. The residual error can be compressed with any suitable method, *e.g.* using DCT as in current standards.

The system according to the invention consists of two main parts, as illustrated in Figure 2. First, context-dependent selection 17 of a suitable subset of prediction methods is performed by classifying neighbouring reconstructed blocks. Second, prediction block is constructed 18 using one of the prediction methods in the selected subset and the prediction method is signalled to decoder.

Context-dependent selection of a prediction method subset comprises directionality classification of possible neighbouring blocks, mapping of directionality classes to context classes and context-dependent selection of an appropriate prediction method subset.

In the following, the transmission and reception of digital image frames in a transmission system is described with reference to the digital image transfer arrangement presented in Figure 1. The current frame arrives at the transmission system 1 as input data 2 provided, for example, as the output of a digital video camera. The current frame may be provided in its entirety (*i.e.* a complete frame comprising NxM image blocks), in which case the frame is stored, or the transmission system 1 may receive the input data block by block. The blocks of the frame are directed one by one to a summer 4, where prediction error of a block is calculated *e.g.* by subtracting blocks of the frame from predicted blocks. The prediction error is coded in a coder 5 and decoded in a decoder 6. In summer 7 decoded prediction error is summed with predicted blocks and the result is saved in a frame memory 8. The prediction estimator 3, where spatial prediction of a pixel is performed for every block, according to the method of the invention, receives blocks to be used with prediction from the frame memory 8.

In order to form a new prediction block, the prediction estimator 3 examines, if there exists some directionality in possible neighbouring blocks of the current block. This scheme is illustrated in Figure 3a. The reference C denotes the current block, the reference L denotes the first

neighbouring block of the current block and the reference U denotes the second neighbouring block of the current block. The first neighbouring block is to the left of the current block C and the second neighbouring block is above the current block C in this advantageous embodiment of the invention. If the scanning order is different from left to right and from top to bottom, the first neighbouring block L and the second neighbouring block U are not necessarily to the left of and above the current block C, respectively. The neighbouring blocks L, U are such blocks which are adjacent to the current block C and which already are reconstructed. Furthermore, in some embodiments of the invention there can be more than two blocks which are classified and used to select the prediction method for the current block C. In the following description of the invention, however, at most two neighbouring blocks L, U are classified for each block C under examination. Furthermore, the classification is performed only if a neighbouring block L or U exists. If a current block does not have any neighbouring blocks, it is treated as "Non-Intra" during the context-dependent selection of prediction methods, as will be explained further later in the text.

Prediction can also be implemented in such a way that it is performed using only already reconstructed intra-coded blocks. In this case, all blocks other than intra-coded blocks are treated as "Non-Intra".

The first neighbouring block L and the second neighbouring block U are classified according to the directionality of image details inside the block. The directionality classifier 19 analyses the directionality of the neighbouring blocks using pixel value gradients. As a result, each neighbouring block is mapped 20 into an output class. In an advantageous embodiment of the invention there are 11 such output classes, but it is obvious that the number of output classes may vary. These output classes consist advantageously of 8 directionality classes D0 – D7 corresponding to edge orientations $k \bullet 22.5°$, $k = 0, 1, \ldots, 7$ and 3 non-directional classes D8 – D10 corresponding to flat, smooth texture and coarse texture blocks.

In the system of figure 1, the prediction estimator 3 first examines, if the first neighbouring block L and/or the second neighbouring block U exist.

If either one of these blocks does not exist, that neighbouring block is defined as a C0 block ("Non-Intra"), *i.e.* the current block C is on the edge or in a corner of the frame, or on the edge or in a corner of an area consisting of Intra blocks. Then, the prediction estimator 3 selects a suitable prediction method for the current block C which is described later in this description. Otherwise the prediction estimator 3 calculates gradient information relating to the block or blocks L, U.

There are many suitable methods for calculating the gradient information. In the following, one advantageous method is described. First, average absolute directional gradients g_k, k = 0, 1, ... , 7 of a block L, U are defined as

$$
\begin{aligned}
g_0 &= \frac{1}{N(N-1)}\max\left(1, \sum_{y=0}^{N-1}\sum_{x=0}^{N-2}\left|I(x,y)-I(x+1,y)\right|\right)\\
g_1 &= \frac{1}{(N-1)^2}\max\left(1, \sum_{y=0}^{N-2}\sum_{x=1}^{N-1}\left|I(x,y)-\tfrac{1}{2}\left(I(x-1,y)+I(x-1,y+1)\right)\right|\right)\\
g_2 &= \frac{1}{(N-1)^2}\max\left(1, \sum_{y=0}^{N-2}\sum_{x=1}^{N-1}\left|I(x,y)-I(x-1,y+1)\right|\right)\\
g_3 &= \frac{1}{(N-1)^2}\max\left(1, \sum_{y=0}^{N-2}\sum_{x=1}^{N-1}\left|I(x,y)-\tfrac{1}{2}\left(I(x-1,y+1)+I(x,y+1)\right)\right|\right)\\
g_4 &= \frac{1}{N(N-1)}\max\left(1, \sum_{y=0}^{N-2}\sum_{x=0}^{N-1}\left|I(x,y)-I(x,y+1)\right|\right)\\
g_5 &= \frac{1}{(N-1)^2}\max\left(1, \sum_{y=0}^{N-2}\sum_{x=0}^{N-2}\left|I(x,y)-\tfrac{1}{2}\left(I(x,y+1)+I(x+1,y+1)\right)\right|\right)\\
g_6 &= \frac{1}{(N-1)^2}\max\left(1, \sum_{y=0}^{N-2}\sum_{x=0}^{N-2}\left|I(x,y)-I(x+1,y+1)\right|\right)\\
g_7 &= \frac{1}{(N-1)^2}\max\left(1, \sum_{y=0}^{N-2}\sum_{x=0}^{N-2}\left|I(x,y)-\tfrac{1}{2}\left(I(x+1,y)+I(x+1,y+1)\right)\right|\right)
\end{aligned}
\tag{1}
$$

where N is the size of the block and I(x,y) represent the pixel intensity values. Indices x and y refer to coordinates of pixel inside the block and

k represents edge orientations. The prediction estimator 3 calculates the gradient values g_k according to the formulae above.

Using the gradient values g_k, gradient ratios r_k, $k = 0, 1, \ldots, 7$ are defined as the ratio between the gradient value in a certain direction and gradient value in the orthogonal direction:

$$
\begin{array}{llll}
r_0 = \dfrac{g_0}{g_4}, & r_1 = \dfrac{g_1}{g_5}, & r_2 = \dfrac{g_2}{g_6}, & r_3 = \dfrac{g_3}{g_7} \\
r_4 = \dfrac{1}{r_0}, & r_5 = \dfrac{1}{r_1}, & r_6 = \dfrac{1}{r_2}, & r_7 = \dfrac{1}{r_3}
\end{array}
\qquad (2)
$$

Based on the absolute gradient values g_k and gradient ratios r_k defined in (1) and (2), classification of the block is performed advantageously using the following classification steps 1—12 with some numerical values as thresholds. This classification process classifies each of the neighbouring blocks into one of a first set of block types D0—D10. The present invention is not limited to the values used in the algorithm, but the values used in the algorithm in the following steps are preferred. The method can also be applied to any block size.

In this advantageous embodiment of the invention the classification phase comprises 13 steps, but it is obvious that the classification may comprise also different number of steps.

<u>Step 1</u>

In this step the flatness of the block is checked. Prediction estimator 3 calculates gradient values g_0 and g_4. These correspond to gradient values for horizontal (0°) and vertical (90°) image details. If both $g0 \le 2.0$ and $g4 \le 2.0$, the block is classified as D8 and the initial classification process terminates. Otherwise classification step 2 is performed.

<u>Step 2</u>

In this step a further check for flatness of the block is performed. The rest of the gradient values g_k are calculated, and the maximum gradient value $g_{max} = \max\{g_k\}$ is explored. The maximum gradient value g_{max} is compared with 2.5. If $g_{max} \le 2.5$ the block is classified as D8 and the

initial classification process terminates. Otherwise the method continues from step 3.

Step 3

In step 3 a check for clear directionality is performed. The gradient ratios r_k are calculated and the minimum gradient ratio $r_{min} = \min\{r_k\}$ is determined. When the minimum gradient ratio is found, the corresponding index k_{min} is defined. If $r_{min} \leq 0.15$ the block is classified to corresponding class Dk_{min} and the method continues from step 12, otherwise the method continues from step 4.

Step 4

In step 4 a check for texture is performed. The minimum gradient ratio r_{min} is compared with 0.6. If $r_{min} \geq 0.6$ the method continues from step 13, otherwise the method continues from the next step.

Step 5

In step 5 the two smallest gradient ratios are checked to determine if they are clearly distinct. The gradient ratios r_k are sorted in increasing order $r_{(0)} \leq r_{(1)} \leq r_{(2)} \ldots \leq r_{(7)}$. Also the gradient ratio indices are reordered according to the sorted order $k_{(0)}, k_{(1)}, k_{(2)}, \ldots k_{(7)}$. If $r_{(1)} - r_{(0)} < \frac{1}{3}\left(r_{(2)} - r_{(1)}\right)$ the sixth classification step is performed next, otherwise the method continues from the 10th classification step.

Step 6

In step 6 the smallest gradient ratio is checked to determine if it corresponds to context class C2 or C6 and the smallest gradient ratio is small enough. The prediction estimator 3 first examines, whether the index of the gradient ratio $r_{(0)}$ is either 2 or 6, wherein the first gradient ratio $r_{(0)}$ is compared with 0.6. If $r_{(0)} \in \{r_k \mid k = 2,6\}$ and $r_{(0)} < 0.6$, the block is classified as corresponding to class $Dk_{(0)}$ and the method continues from step 12. Otherwise the method continues from step 7.

Step 7

In step 7 the prediction estimator 3 first examines if the index of the second gradient ratio $r_{(1)}$ is either 2 or 6, wherein the first gradient ratio $r_{(0)}$ is compared with 0.6. If $r_{(1)} \in \{r_k \mid k = 2,6\}$ and $r_{(0)} < 0.6$ the block is

classified as corresponding to class $Dk_{(1)}$ and the method continues from the step 12, otherwise the method continues from Step 8.

Step 8

In step 8 the smallest gradient ratio is checked to determine if it corresponds to context class C1, C3, C5 or C7 and the smallest gradient ratio is small enough. The first gradient ratio $r_{(0)}$ is compared with 0.5. If $r_{(0)} \in \{r_k \mid k = 1,3,5,7\}$ and $r_{(0)} < 0.5$ the block is classified as corresponding to class $Dk_{(0)}$ and the method continues from step 12, otherwise the method continues from step 9.

Step 9

In step 9 the second gradient ratio is checked to determine if it corresponds to context class C1, C3, C5 or C7 and the smallest gradient ratio is small enough. The first gradient ratio $r_{(0)}$ is compared with 0.5, if $r_{(1)} \in \{r_k \mid k = 1,3,5,7\}$. If $r_{(0)} < 0.5$ the block is classified as corresponding to class $Dk_{(1)}$ and the method continues from step 12. Otherwise the method continues from step 10.

Step 10

Directionality is not yet found, therefore a (little bit) higher threshold value compared with the threshold value used in Step 3 can be tried for checking the directionality. This means that more uncertain examination is performed. Step 10 uses the values of threshold T_1 defined in Table 1, below. The values for T_1 are compared with the first gradient ratio. If $r_{(0)} < T_1$ defined in Table 1 the block is classified as corresponding to class $Dk_{(0)}$ and the method continues from step 12. Otherwise the method continues from step 11.

Orientation Relation for $r_{(0)}$	T_1
$r_{(0)} \in \{r_k \mid k = 2,6\}$	0.5
$r_{(0)} \in \{r_k \mid k = 1,3,5,7\}$	0.4
$r_{(0)} \in \{r_k \mid k = 0,4\}$	0.3

Table 1

Step 11

Directionality is not yet found, therefore in step 11 the three smallest gradient ratios are checked to find out if they are neighbours and if the smallest gradient ratio is in the middle. In that case a still higher threshold value compared with the threshold value used in Step 3 can be tried for checking the directionality. This means that more uncertain examination is performed. Step 11 uses the values of threshold T_2 defined in Table 2, below. Then, if the directionalities corresponding to the second $r_{(1)}$ and the third gradient ratios $r_{(2)}$ are the closest neighbours for the directionality corresponding to the first gradient ratio $r_{(0)}$ and $r_{(0)} < T_2$ defined in Table 2, the block is classified as corresponding to class $Dk_{(0)}$ and the method continues from step 12. Otherwise the method continues from step 13.

Orientation Relation for $r_{(0)}$	T_2
$r_{(0)} \in \{r_k \mid k = 2,6\}$	0.6
$r_{(0)} \in \{r_k \mid k = 1,3,5,7\}$	0.5
$r_{(0)} \in \{r_k \mid k = 0,4\}$	0.4

Table 2

Step 12

Step 12 performs a check that classification is really based on an edge in the image with a certain orientation rather than texture. Step 12 uses the values of threshold T_3 defined in Table 3, below. In Table 3 values for only two possible block sizes (8x8, 4x4) are shown, but in practical embodiments other block sizes can also exist, wherein respective values for T_3 must be defined. In step 12 the minimum gradient value $g_{min} = \min\{g_k\}$ is examined. Depending on the classification and the size of the block, the threshold T_3 is chosen from Table 3. If $g_{min} \leq T_3$ the initial classification process terminates. Otherwise the method continues from step 13.

Classification of the Block	T_3 for 4x4 Block	T_3 for 8x8 Block
D2 and D6	9.0	7.0
D1, D3, D5 and D7	11.5	9.0
D0, D4	14.0	11.0

Table 3

Step 13

Step 13 performs a check whether texture is smooth or coarse. The maximum gradient value g_{max} is compared with 10.0. If $g_{max} \leq 10.0$ the block is classified as D9. Otherwise the block is classified as D10. Step 13 is not necessarily needed, if both smooth and coarse texture are mapped into the same context class.

Next the selection 21 of a suitable prediction method is performed for the current block C. In the preferred embodiment of the invention the selection phase is preceded by a mapping phase. The purpose of the mapping is to reduce the memory consumption of the implementation. Some of the directionality classes can be mapped together. The classes resulting from the mapping phase are called as context classes and they are referred as references C1 – C6. In the preferred embodiment of the invention the diagonal classes are combined to two alternative classes, one for the bottom-left to top-right diagonality and the other for the top-left to bottom-right diagonality.

Mild and steep diagonal classes D5, D6 and D7 are mapped to the first diagonal context class C4. Similarly, classes D1, D2 and D3 are mapped to the second diagonal context class C5. Further, the smooth texture class D9 and coarse texture class D10 are mapped together to produce texture context class C6. This mapping is illustrated in Figure 4.

In addition to the 6 context classes C1—C6 there is one further context class C0 used for "Non-Intra" blocks. In general, a "Non-Intra" block is a block that does not exist, i.e. when block C is at the image boundary. If the prediction is implemented in such a way that only intra-coded blocks are used as a reference, the definition of a "Non-Intra" block is extended to those blocks that are not intra-coded.

In the preferred embodiment of the invention there are a total of 13 different prediction methods, which are depicted in Figures 5a—5p for 8x8 blocks. Prediction methods for other block sizes and context classes can be derived similarly. In each case, prediction is performed in a causal manner using neighbouring reconstructed intra-coded

blocks L, U, UL, UR as a reference. The region used for prediction depends on the prediction method as depicted in Figures 3a and 3b where block C is the current block to be coded. In case of prediction methods P1—P12, the region from which blocks may be used for prediction is the area covered by four neighbouring blocks L, UL, U and R as shown in Figure 3b. For prediction method P13, this region is larger, as depicted in Figure 3c.

In an advantageous embodiment of the method according to the invention, a subset of prediction methods for each context class combination is defined and the prediction methods are prioritized (ranked) in each subset. Then, the prediction method used to predict the content of the current block C is selected from a subset of prediction methods. The prediction methods within a subset differ from each other and correspond to those prediction methods that are most likely to provide an accurate prediction for block C, in the event of particular classifications being obtained for neighbouring blocks like L and U. One advantageous definition for the subsets is presented in Table 4 below.

Effectively, the results of context classification for the first neighbouring block L and second neighbouring block U are combined, *i.e.* both taken into consideration when selecting a prediction method for block C. The subset of prediction methods is selected from Table 4 according to the context information of the neighbouring blocks L, U. Each row of Table 4 defines the prediction method subset for a certain pair of context classes for neighbouring blocks L, U and the priority (rank) of the prediction methods in the subset. Ranking is used to simplify for the context-dependent signalling of the prediction methods, as described later in this description. For example, if the first neighbouring block L is classified into context class C2 and the second neighbouring block U is classified into context class C4, the subset for this combination comprises prediction methods P1, P9, P5, P13, P7 and P6 (in ranking order). The prediction estimator 3 further selects the most appropriate prediction method from this subset, as detailed later in this description.

L Class	U Class	Rank of Prediction Methods					
		Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6
C0	C0	P1	P5	P11	P9	P8	P4
	C1	P1	P9	P5	P8	P2	P13
	C2	P1	P5	P2	P13	P11	P3
	C3	P5	P13	P1	P9	P12	P7
	C4	P1	P8	P5	P9	P6	P7
	C5	P1	P8	P5	P3	P2	P10
	C6	P1	P5	P9	P13	P8	P12
C1	C0	P9	P1	P2	P13	P8	P10
	C1	P9	P1	P13	P2	P5	P10
	C2	P9	P1	P2	P5	P3	P11
	C3	P9	P5	P1	P13	P4	P11
	C4	P9	P1	P13	P5	P3	P7
	C5	P9	P1	P13	P2	P8	P10
	C6	P9	P1	P13	P5	P11	P2
C2	C0	P1	P9	P10	P11	P12	P7
	C1	P9	P1	P10	P5	P11	P2
	C2	P1	P11	P10	P2	P3	P12
	C3	P5	P1	P11	P9	P4	P13
	C4	P1	P9	P5	P13	P7	P6
	C5	P1	P9	P10	P11	P2	P7
	C6	P1	P11	P9	P5	P12	P10
C3	C0	P5	P1	P12	P9	P13	P7
	C1	P1	P9	P5	P13	P3	P11
	C2	P5	P1	P9	P4	P13	P3
	C3	P5	P1	P13	P9	P12	P11
	C4	P1	P5	P9	P6	P13	P7
	C5	P1	P5	P9	P13	P3	P6
	C6	P5	P1	P11	P13	P9	P12
C4	C0	P1	P9	P7	P8	P6	P13
	C1	P9	P1	P5	P13	P8	P7
	C2	P1	P5	P9	P13	P7	P11
	C3	P5	P1	P13	P9	P7	P11
	C4	P1	P13	P7	P9	P5	P8
	C5	P1	P7	P9	P13	P8	P4
	C6	P1	P9	P13	P5	P7	P8
C5	C0	P1	P9	P10	P11	P6	P7
	C1	P1	P9	P5	P8	P10	P13
	C2	P1	P5	P11	P4	P13	P10
	C3	P5	P1	P13	P10	P6	P4
	C4	P1	P8	P5	P13	P10	P7
	C5	P1	P9	P3	P5	P8	P13
	C6	P1	P9	P5	P13	P10	P8
C6	C0	P1	P9	P2	P5	P6	P11
	C1	P9	P1	P5	P13	P2	P3
	C2	P1	P9	P5	P13	P2	P11
	C3	P5	P1	P9	P13	P12	P11
	C4	P1	P9	P5	P10	P7	P13
	C5	P1	P9	P13	P2	P5	P7
	C6	P1	P9	P5	P13	P11	P12

Table 4

In the following, the defined prediction methods are described in more detail.

Prediction method P1

Prediction method P1 predicts the average pixel value of block C from the average pixel values of blocks L, UL, U and UR. The average pixel values dL, dUL and dU of the reconstructed blocks L, UL, and U are calculated as the integer division defined as

$$d = \left(\sum_{x=0,y=0}^{N-1,N-1} I(x,y) + \tfrac{1}{2}N^2 \right) // N^2 \qquad (3)$$

where N is the size of the block, I(x,y) represent the pixel intensity values and "//" denotes division with truncation to integer value. The average pixel value dC of block C is predicted according to following set of rules (which are written below in the form of pseudo-code):

```
if all blocks L, U and UL exist then
        if dL = dU = dUL then      dC = dUL
        else if dUL = dU then      dC = dL
        else if dUL = dL then      dC = dU
        else if dL = dU then
                if chrominance prediction then   dC = dL
                else if | dUL - dL | < 4 then    dC = s(dL + dU - dUL)
                else   dC = dL
        else if dUL < dL < dU then         dC = dU
        else if dUL < dU < dL then         dC = dL
        else if dU < dL < dUL then         dC = dU
        else if dL < dU < dUL then         dC = dL
        else if dL < dUL < dU OR dU < dUL < dL then
                                           dC = s(dL + dU - dUL)
else if blocks L and U exist then dC = (dL + dU +1) // 2
else if blocks L and UL exist then         dC = dL
else if blocks U and UL exist then         dC = dU
else if block L exists then        dC = dL
else if block U exists then        dC = dU
else if block UL exists then       dC = dUL
else                               dC = p
```

where p is a value that is in the middle of the possible pixel value range, *e.g.* 128, "//" denotes division with truncation and s is a clipping function that restricts the values to the possible range of pixel values, e.g. between 0 and 255 in a system that uses an 8-bit representation of luminance/chrominance values. As a result, prediction block for C is filled with pixels having a constant value given by dC.

<u>Prediction method P2—P4</u>

Prediction methods P2 through P4 predict diagonal shapes in block C by extending image details from the upper right direction into block C. Prediction is performed by copying reference pixel values at the boundaries of blocks U and UR into block C as depicted in Figures 5b, 5c, 5d. Reference pixels that are marked in gray are connected to one or more predicted pixels. The connection is marked as line with dots to indicate connected predicted pixels. the value of the reference pixel is copied to all connected predicted pixels.

Since one or more reference blocks might be unavailable, i.e. their context class may be C0, prediction is performed according to following rules.

<u>Rule 1</u>

If both blocks, U and UR, are classified into one of classes C1 – C6, pixel prediction is performed as shown in Figures 5b, 5c and 5d respectively. For prediction method P2, pixels without any corresponding reference pixel in block UR are advantageously allocated the value of the rightmost reference pixel in block UR.

<u>Rule 2</u>

If block U is classified into one of classes C1 – C6 and block UR is classified as C0, pixel prediction is performed as shown in Figures 5b, 5c and 5d for pixels that have a reference pixel in block U. The rest of the pixels are advantageously set to the value of the pixel in the lower right corner of the reference block U.

<u>Rule 3</u>

If block U is classified as C0, the current block C is advantageously filled with pixels having a constant value that is substantially in the

middle of the possible dynamic range of pixel values, e.g. 128 (in a system, that uses an 8-bit representation of luminance/chrominance values).

Prediction method P5 and P9

Prediction methods P5 and P9 predict vertical and horizontal shapes in the current block C by extending image details either from above or from the left into the current block C. Depending on the selected method (P5 or P9), the reference pixel values at the boundary of either block U or L are copied to the current block C as depicted in Figures 5e and 5i.

If the context class of the reference block is C0 then the current block C is advantageously filled with pixels having a constant value that is substantially in the middle of the possible dynamic range of pixel values, e.g. 128 (in a system, that uses an 8-bit representation of luminance/chrominance values).

Prediction method P6, P7 and P8

Prediction methods P6, P7 and P8 predict diagonal shapes in the current block C by extending image details from the upper left direction into the current block C as depicted in Figures 5f, 5g and 5h. Prediction is performed by copying reference pixel values at the boundaries of blocks L, UL and U into the current block C according to following rules.

Rule 1

If all blocks L, UL and U are classified into one of classes C1 – C6, the pixel prediction for the current block C is performed as illustrated in Figures 5f, 5g and 5h.

Rule 2

If blocks UL and U are classified into one of classes C1 – C6 and block L is classified as C0, pixel prediction for the current block C is performed as shown in Figures 5f, 5g and 5h for those pixels of the current block C that have a reference pixel in blocks UL and L. The remaining pixels in the current block C are advantageously assigned the value of the pixel in the lower left corner of the reference pixel area in block UL.

Rule 3

If blocks L and UL are classified into one of classes C1 – C6 and block U is classified as C0, pixel prediction for the current block C is performed as shown in Figures 5f, 5g and 5h for those pixels of the current block C that have a reference pixel in blocks L and UL. The remaining pixels in the current block C are advantageously assigned the value of the pixel in the upper right corner of the reference pixel area in block UL.

Rule 4

If blocks L and U are classified into one of classes C1 – C6 and block UL is classified as C0, pixel prediction for the current block C is performed as shown in Figures 5f, 5g and 5h for those pixels of the current block C that have a reference pixel in blocks L and U. Pixels with reference pixel in block UL are predicted as shown in Figures 5n, 5o and 5p. In case of method P7, the predicted pixel value is the average of the two reference pixel values rounded to the nearest integer value, as indicated in Figure 5o.

Rule 5

If block L is classified into one of classes C1 – C6 and blocks UL and U are classified as C0, pixel prediction for the current block C is performed as shown in Figures 5f, 5g and 5h for those pixels of the current block C that have a reference pixel in block L. The remaining pixels in the current block C are advantageously assigned the value of the pixel in the upper right corner of the reference pixel area in block L.

Rule 6

If block UL is classified into one of classes C1 – C6 and blocks L and U are classified as C0, pixel prediction for the current block C is performed as shown in Figures 5f, 5g and 5h for those pixels of the current block C that have a reference pixel in blocks UL. Pixels of the current block C that have a reference pixel in block L are advantageously assigned the value of the lower/left reference pixel in block UL. Pixels of the current block C that have a reference pixel in block U are assigned the value of the upper/right reference pixel in block UL.

Rule 7

If block U is classified into one of classes C1 – C6 and blocks L and UL are classified as C0, pixel prediction for the current block C is performed as shown in Figures 5f, 5g and 5h for those pixels of the current block C that have a reference pixel in block U. The remaining pixels of the current block C are advantageously assigned the value of the pixel in the lower left corner of the reference pixel area in block U.

Rule 8

If all blocks L, UL and L are classified as C0, the current block C is advantageously filled with pixels having a constant value that is substantially in the middle of the possible dynamic range of pixel values, e.g. 128 (in a system, that uses an 8-bit representation of luminance/chrominance values).

Prediction method P10, P11 and P12

Prediction methods P10 through P12 predict diagonal shapes in the current block C by extending image details from the left into the current block C as depicted in Figures 5j, 5k and 5l. Prediction is performed by copying reference pixel values at the boundary of blocks L into the current block C according to following rules.

Rule 1

If block L is classified into one of classes C1 – C6, the pixel prediction for the current block C is performed as illustrated in Figures 5j, 5k and 5l. Pixels of the current block C without reference pixel in block L are advantageously filled with the value of the pixel in the lower right corner of the reference pixel area.

Rule 2

If block L is classified as C0, the current block C is advantageously filled with pixels having a constant value that is substantially in the middle of the possible range of pixel values, e.g. 128 (in a system, that uses an 8-bit representation of luminance/chrominance values).

Prediction method P13

Prediction method P13 predicts the content of the current block C from the neighbouring image content by examining if there exists a range of pixels having values which substantially corresponds to the pixel values of the current block C. The prediction of the current block C is performed by copying reconstructed pixel values from a reference block B that is inside a search range SR as depicted in Figure 5m. Search range SR is defined by lists of horizontal (x) and vertical (y) displacements. Each pair of horizontal displacement and corresponding vertical displacement values (x, y) defines a displacement vector between the coordinates of upper left corner of the current block C and upper left corner of the reference block B. Prediction is allowed only for those displacements corresponding to reference block B that is completely inside the reconstructed part of the frame. Examples of displacement pairs using 512 displacements for 8x8 blocks are presented in Tables 9a and 9b. In this example the scanning order of the tables is from top-left to bottom-right row by row.

The list of allowed displacements is known to both the encoder and the decoder, allowing context-dependent signaling of the selected reference block location.

There are many alternative ways to select the prediction method from a subset of prediction methods. For example, a cost function can be defined in order to evaluate the effectiveness of the different prediction methods of the subset to be used. The cost function maybe calculated on the basis of information concerning the error incurred when predicting a current block C using a particular prediction method. This error denotes differences between actual pixel values and reconstructed pixel values. Typically, the error values for each pixel on the current block C are squared and summed together to produce a squared error measure for the whole block. The cost function may also comprise information concerning the number of bits, *i.e.* the bit rate needed to transfer the information to the receiver. The elements of the cost function, particularly the bit rate, can also be weighted to emphasize them. One example of the cost function is

$$Cx = D + \lambda R, \qquad (4)$$

where cost Cx is defined as a weighted sum of distortion D and rate R associated with each of the prediction methods and λ is the weighting factor. If the transmission system is band limited, the weight value is typically larger than if the bandwidth is wider. Now, the values for the formula (4) are calculated with different prediction methods and preferably that one is selected which results the smallest value for the cost function.

Additionally, the prediction error information can also be coded prior to transmission to the receiver. Advantageously, there is a subset of coding methods defined for each prediction method. Specifically, the coding method could be chosen to minimise the number of bits required to encode the prediction error. For example, the effectiveness (bit rate) of the coding method is examined.

If the prediction error is relatively small, it may not be necessary to transmit the prediction error information at all.

When the suitable prediction method is selected, the prediction estimator 3 performs spatial prediction 22 according to the selected prediction method. The prediction estimator 3 directs the reconstructed block to summer 4 where the reconstructed block is subtracted from the actual contents of the current frame C to produce prediction error information for the current block.

The encoder 1 sends 23 the information about the selected prediction method to the multiplexer 9, which is followed by displacement information if method P13 is used. Encoding of the information is advantageously performed using variable length coding.

The information is further transmitted to the receiver 10, where the demultiplexer 11 demultiplexes the received information. In the receiver 10 the prediction information is directed to the predictor 16. The receiver 10 comprises also a frame memory 14, where the previously reconstructed blocks are saved. When a new coded block arrives to the receiver, the predictor 16 performs the classifying steps for the neighbouring blocks U, L of the received, current block C. Then the

predictor 16 carries out the mapping of classification information into context classes C1 – C6. After that the predictor 16 examines also the rank of the prediction method. The receiver 10 contains the information of the Table 4 and 5, wherein the predictor 16 can determine the correct subset of the prediction methods according to the context class combination and the rank.

When the prediction method is discovered, the predictor 16 can reconstruct the current block C and save it to the frame memory 14. In a situation where also prediction error information is received, that information is first decoded in the decoder 12, if necessary, and combined with the pixel values of the reconstructed block C. Now the current block C is ready to direct to the output 15 of the receiver.

If the prediction method of the current block C is P13, the reconstruction of the current block C is performed in a slightly different manner. The receiver 10 has to decode also the displacement information, wherein the displacement information is used to copy the pixel values of the current block C from previously reconstructed pixel values in the frame memory 14.

Signalling of the prediction method is advantageously based on the context-dependent codes defined in Table 5. After selecting the appropriate prediction method, the encoder 1 sends a variable length codeword that corresponds to the rank of the selected prediction method in the context-dependent subset. Advantageous examples of variable length codewords representing each prediction method rank are listed in Table 5. For example, if the first neighbouring block L is classified into context class C3 and the second neighbouring block U is classified into context class C1, and the prediction method P9 is selected from the subset of the prediction methods for this combination, the respective rank is 2. Then, the codeword which corresponds this rank is "01".

Rank	Code	Length
1	1	1
2	01	2
3	0000	4
4	0001	4
5	0010	4
6	0011	4

Table 5

The receiver 10 is aware of the contents of Table 4, *i.e.* it knows which prediction method corresponds to each of the ranks in every possible context (combination of classes for the neighbouring blocks L and U). Since the receiver 10 can derive the same context information as the prediction estimator 3, receiver 10 can associate the rank represented by the received codeword to correct prediction method and perform the spatial prediction for block C according to the method.

In an advantageous embodiment of the invention the signalling of horizontal and vertical displacements associated with prediction method P13 is performed as follows:

<u>Step 1</u>

Those pairs of horizontal and vertical displacements (X(i), Y(i)) that correspond to reference blocks B lying partially or entirely outside the frame are eliminated from the ordered list given in Tables 9a, 9b. The number of valid pairs is denoted by Nv and the ordered list of valid pairs which are retained after the elimination is denoted by Lv.

<u>Step 2</u>

The rank r (which is one of 1, 2, ..., Nv) corresponding to the chosen block B within the list Lv created in Step 1 is calculated.

<u>Step 3</u>

Based on the value of rank r determined in Step 1 the value $index_1$ is calculated according to Table 6 is calculated.

Step 4

The value $index_2 = r - OffsetLow(index_1)$ is calculated using the values listed in Table 6.

Range for rank *r*	*index*$_1$	*OffsetLow* (*index*$_1$)	*OffsetHigh* (*index*$_1$)	*AuxLength* (*index*$_1$)
1, ..., 2	1	1	2	1
3, ..., 4	2	3	4	1
5, ..., 6	3	5	6	1
7, ..., 8	4	7	8	1
9, ..., 12	5	9	12	2
13, ..., 16	6	13	16	2
17, ..., 24	7	17	24	3
25, ..., 32	8	25	32	3
33, ..., 48	9	33	48	4
49, ..., 64	10	49	64	4
65, ..., 96	11	65	96	5
97, ..., 128	12	97	128	5
129, ..., 192	13	129	192	6
193, ..., 256	14	193	256	6
257, ..., 384	15	257	384	7
385, ..., 512	16	385	512	7

Table 6

Step 5

Next, a variable *bits* is calculated as follows. If $Nv < OffsetHigh(index_1)$, the value for the variable *bits* is computed advantageously with formula *bits* = [log2(1 + Nv - OffsetLow(index1))], where [x] denotes the nearest integer $\geq$ x. Otherwise, *bits* = AuxLength(index1).

Step 6

Depending on the value of Nv the variable whose sub-script is $index_1$ is encoded using the corresponding Variable Length Coding given in Table 7 and Table 8. This codeword is transmitted to the decoder, which is illustrated with block CW1 in Figure 6.

Step 7

If the variable *bits* is nonzero the binary representation of index2 is encoded using a number of bits corresponding to the value of variable *bits* and this codeword is transmitted to the receiver, which is illustrated with block CW2 in Figure 6.

N_V in range 1, … , 16			N_V in range 17, … , 32			N_V in range 33, … , 64		
VLC_A			VLC_B			VLC_C		
Symbol	Length	Code	Symbol	Length	Code	Symbol	Length	Code
A_1	2	11	B_1	1	1	C_1	2	11
A_2	3	001	B_2	2	01	C_2	3	101
A_3	2	10	B_3	4	0011	C_3	4	0011
A_4	4	0001	B_4	4	0010	C_4	5	00001
A_5	2	01	B_5	5	00011	C_5	3	100
A_6	4	0000	B_6	5	00010	C_6	4	0010
			B_7	5	00001	C_7	4	0001
			B_8	5	00000	C_8	5	00000
						C_9	3	011
						C_{10}	3	010

Table 7

N_V in range 65, … , 128			N_V in range 129, … , 256			N_V in range 257, … , 512		
VLC_D			VLC_E			VLC_F		
Symbol	Length	Code	Symbol	Length	Code	Symbol	Length	Code
D_1	2	11	E_1	2	11	F_1	3	111
D_2	3	101	E_2	3	101	F_2	4	1011
D_3	5	00001	E_3	4	0111	F_3	4	1010
D_4	5	00000	E_4	5	00011	F_4	6	000001
D_5	4	0111	E_5	4	0110	F_5	4	1001
D_6	4	0110	E_6	5	00010	F_6	5	00001
D_7	3	100	E_7	4	0101	F_7	4	1000
D_8	4	101	E_8	4	0100	F_8	4	0111
D_9	4	0100	E_9	3	100	F_9	4	0110
D_{10}	4	0011	E_{10}	4	0011	F_{10}	4	0101
D_{11}	4	0010	E_{11}	4	0010	F_{11}	4	0100
D_{12}	4	0001	E_{12}	5	00001	F_{12}	4	0011
			E_{13}	6	000001	F_{13}	3	110
			E_{14}	6	000000	F_{14}	4	0010
						F_{15}	4	0001
						F_{16}	6	000000

Table 8

X[512] =

-8	-8	-8	-1	-10	-8	0	1	-16	-9	-8	-8	-18	-8	-12	-11
-14	-11	-19	-15	-10	-10	-9	-16	-9	-9	-14	-13	-13	-2	-12	-11
-8	3	-15	0	-19	-15	-3	0	-10	11	2	-13	-11	0	-12	-19
1	-18	-17	-11	-10	-14	-1	18	-7	-5	-12	-10	-8	-13	-9	-9
0	-14	21	5	-3	10	-10	-15	-14	-13	19	-11	-10	-11	14	0
-19	-13	-16	4	-12	-4	-16	3	12	-13	-19	7	-19	-13	-4	-15
-10	1	-12	-17	0	0	-16	-16	-15	-11	1	-16	-18	-12	-8	-18
-15	-6	0	-13	-18	-2	16	17	-12	-9	2	8	-12	16	18	-9
-19	-19	4	-11	-18	-18	0	15	15	19	-6	-14	16	14	-16	8
-16	-17	13	0	-1	-12	16	-17	-8	-16	-16	-1	-15	-1	-18	-17
5	6	4	8	5	-11	-16	-2	-7	2	-14	4	-17	-13	-2	13
-5	-18	-19	-17	-9	-6	-16	13	-15	0	13	-19	6	-5	-14	-5
1	-19	-1	-17	-12	-13	-6	12	-8	-13	-14	3	17	-14	-14	-11
12	-1	5	-11	-2	-4	3	-1	-2	5	-9	1	-12	14	9	1
-9	20	-19	18	-17	-1	-12	-3	4	-17	13	-12	-17	-5	-4	-17
-4	-8	9	1	-15	8	7	-1	13	8	-3	-6	-3	-12	-16	-13
-5	16	-13	15	-19	-15	2	12	11	-15	14	-15	-5	7	11	-15
-4	20	-7	4	17	15	-14	3	-10	-14	-15	-15	14	1	-11	12
10	14	5	13	-9	-3	-12	17	-17	-11	9	-3	-1	3	11	-18
-18	-8	-3	7	-4	-13	-14	-17	8	8	-10	-6	16	-7	19	-8
1	-10	19	6	10	4	13	20	3	8	-18	4	15	1	-8	-11
-2	-6	3	6	-14	9	-16	-2	-14	-8	6	-7	-17	7	6	16
-13	5	5	4	-10	-3	-13	10	17	2	6	11	-13	-9	-16	-14
-7	-2	6	-18	9	-8	-11	-7	-7	8	5	9	-3	6	-12	-7
-4	12	12	-8	-6	-9	-11	12	-5	12	-11	4	-14	8	10	5
19	-4	-12	-2	-3	-4	7	12	14	15	-6	7	7	4	11	11
-18	-6	-7	18	10	-10	-10	2	-1	-10	-8	2	-9	13	11	11
17	15	13	2	10	-7	-10	14	-2	4	5	12	-3	-4	17	-5
7	10	13	3	6	-6	-6	-11	9	9	2	-9	-12	3	-9	-10
6	3	14	11	9	8	-5	-7	10	7	-12	14	1	5	-13	2
-11	18	11	12	-4	-5	-9	-10	-9	16	7	15	9	9	10	2
18	10	8	10	15	-15	3	-5	-9	7	-2	2	9	6	11	-10

Table 9a

Y[512] =

-1	-2	-3	-8	-2	0	-8	-8	0	-2	-4	-6	0	-5	0	-2
0	0	-1	0	-1	0	-4	-1	-1	0	-3	-2	0	-8	-2	-1
-7	-8	-2	-14	0	-4	-8	-18	-7	-8	-8	-3	-5	-16	-1	-4
-19	-13	0	-8	-6	-2	-19	-8	-8	-8	-9	-4	-8	-1	-5	-3
-15	-6	-8	-8	-9	-8	-3	-5	-8	-6	-10	-3	-5	-4	-8	-12
-7	-10	-15	-8	-4	-8	-2	-9	-9	-5	-10	-8	-3	-11	-9	-6
-8	-11	-7	-3	-10	-13	-8	-3	-3	-6	-16	-12	-3	-3	-9	-4
-1	-8	-9	-7	-5	-10	-8	-8	-5	-7	-9	-8	-6	-9	-13	-6
-2	-5	-9	-9	-1	-10	-11	-16	-8	-9	-9	-4	-12	-10	-4	-9
-5	-4	-10	-17	-16	-19	-11	-6	-19	-9	-10	-9	-16	-12	-8	-8
-19	-8	-17	-19	-10	-7	-11	-14	-19	-10	-1	-19	-2	-8	-9	-11
-19	-7	-8	-1	-8	-19	-7	-16	-8	-19	-9	-11	-9	-10	-11	-12
-18	-6	-11	-11	-10	-14	-10	-19	-18	-18	-10	-16	-12	-5	-7	-12
-8	-18	-17	-15	-12	-19	-18	-10	-11	-9	-10	-13	-13	-11	-8	-12
-15	-9	-9	-10	-10	-17	-12	-16	-12	-14	-8	-8	-7	-9	-17	-12
-12	-16	-16	-9	-11	-17	-19	-14	-18	-16	-12	-14	-15	-18	-6	-4
-17	-10	-9	-9	-12	-14	-12	-10	-19	-12	-17	-7	-11	-12	-16	-9
-13	-8	-9	-16	-14	-10	-13	-11	-14	-12	-10	-13	-16	-10	-19	-13
-12	-12	-15	-17	-16	-10	-17	-10	-5	-16	-18	-18	-13	-19	-9	-6
-2	-17	-19	-11	-10	-15	-15	-13	-14	-18	-19	-17	-15	-13	-8	-14
-14	-11	-12	-14	-11	-13	-14	-10	-10	-10	-9	-14	-12	-17	-10	-18
-13	-12	-17	-18	-14	-10	-14	-19	-9	-12	-10	-11	-9	-9	-16	-14
-13	-16	-12	-10	-9	-14	-12	-15	-13	-16	-12	-18	-17	-13	-13	-16
-12	-15	-17	-11	-17	-15	-13	-15	-17	-15	-11	-15	-17	-11	-14	-14
-14	-14	-15	-13	-16	-18	-17	-16	-15	-17	-14	-15	-17	-13	-19	-13
-11	-16	-16	-16	-11	-15	-15	-12	-9	-13	-18	-16	-13	-18	-17	-10
-12	-11	-10	-12	-9	-15	-13	-14	-15	-17	-11	-18	-9	-13	-14	-15
-11	-11	-15	-11	-17	-16	-12	-15	-18	-11	-14	-18	-13	-18	-9	-13
-17	-14	-12	-14	-19	-13	-15	-10	-9	-12	-19	-17	-15	-12	-14	-16
-15	-15	-14	-11	-11	-11	-14	-18	-10	-10	-11	-13	-15	-18	-16	-15
-11	-11	-12	-11	-11	-16	-11	-10	-12	-13	-14	-14	-14	-19	-16	-13
-9	-18	-12	-13	-15	-15	-13	-18	-19	-18	-17	-17	-13	-13	-13	-18

Table 9b

Since the decoder can derive the ordered list of valid displacement vectors, it can associate the rank represented by the received codeword with the correct displacement vector.

The block carrying out prediction method according to the invention is particularly advantageously implemented in a digital signal processor or a corresponding general purpose device suited to processing digital signals, which can be programmed to apply predetermined processing functions to signals received as input data. The measures according to the invention can be carried out in a separate signal processor or they can be part of the operation of such a signal processor which also contains other arrangements for signal processing.

A storage media can be used for storing a software program comprising machine executable steps for performing the method according to the invention. Then in an advantageous embodiment of the invention the software program can be read from the storage media to a device comprising programmable means, *e.g.* a processor, for performing the method of the invention.

A mobile terminal 24 intended for use as a portable teleconferencing device and applying the deblocking filter method according to the invention comprises advantageously at least display means 25 for displaying images, audio means 26 for audio information, keyboard 27 for inputting *e.g.* user commands, radio part 28 for communicating with mobile network, processing means 29 for controlling the operation of the device, memory means 30 for storing information, and preferably a camera 31 for taking images.

The present invention is not solely restricted to the above presented embodiments, but it can be modified within the scope of the appended claims.

Claims:

1. A method for transmitting digital images, in which method at least one frame is formed from the digital image, and the frame is divided into blocks (C, L, U, UL, UR), **characterized** in that in the method a spatial prediction for a block (C) is performed to reduce the amount of information to be transmitted, wherein at least one prediction method (P1—P13) is defined, a classification is determined for at least one neighbouring block (L, U) of said block (C) to be predicted according to the contents of said neighbouring block (L, U), and a prediction method (P1—P13) is selected for the current block (C) on the basis of at least one said classification.

2. A method according to Claim 1, **characterized** in that the classification is determined on the basis of directionality information of the block.

3. A method according to Claim 2, **characterized** in that the directionality information of the block is determined by calculating at lest one gradient value (g_k) on the basis of pixel values of said block.

4. A method according to Claim 3, **characterized** in that the gradient values (g_k) are calculated with the following formula

$$
\begin{aligned}
g_0 &= \frac{1}{N(N-1)} \max\left(1, \sum_{y=0}^{N-1} \sum_{x=0}^{N-2} \left| I(x,y) - I(x+1,y) \right| \right) \\
g_1 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2} \sum_{x=1}^{N-1} \left| I(x,y) - \tfrac{1}{2}\left(I(x-1,y) + I(x-1,y+1)\right) \right| \right) \\
g_2 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2} \sum_{x=1}^{N-1} \left| I(x,y) - I(x-1,y+1) \right| \right) \\
g_3 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2} \sum_{x=1}^{N-1} \left| I(x,y) - \tfrac{1}{2}\left(I(x-1,y+1) + I(x,y+1)\right) \right| \right) \\
g_4 &= \frac{1}{N(N-1)} \max\left(1, \sum_{y=0}^{N-2} \sum_{x=0}^{N-1} \left| I(x,y) - I(x,y+1) \right| \right) \\
g_5 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2} \sum_{x=0}^{N-2} \left| I(x,y) - \tfrac{1}{2}\left(I(x,y+1) + I(x+1,y+1)\right) \right| \right) \\
g_6 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2} \sum_{x=0}^{N-2} \left| I(x,y) - I(x+1,y+1) \right| \right) \\
g_7 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2} \sum_{x=0}^{N-2} \left| I(x,y) - \tfrac{1}{2}\left(I(x+1,y) + I(x+1,y+1)\right) \right| \right) \quad (1)
\end{aligned}
$$

where N is the size of the block, I(x,y) represent the pixel intensity values, indices x and y refer to coordinates of pixel inside the block, and k represents edge orientations.

5. A method according to Claim 4, **characterized** in that at least eight directionality classes (D0 – D7) are defined for different edge orientations.

6. A method according to any of the Claim 1 to 5, **characterized** in that the classification comprises further 3 non-directional classes (D8 – D10) corresponding to flat, smooth texture and coarse texture blocks.

7. A method according to any of the Claim 1 to 6, **characterized** in that in the method at least two context classes (C0 – C6) are defined, therein a mapping phase is performed, in which the classification information (D8 – D10) is mapped into one of said context classes (C0 – C6).

8. A method according to any of the Claim 1 to 7, **characterized** in that in the method a classification is determined for two neighbouring blocks (L, U) of said block (C) to be predicted according to the contents of said neighbouring blocks (L, U), context classes (C0 – C6) are defined for said neighbouring blocks (L, U), and a prediction method (P1—P13) is selected for the current block (C) on the basis of a combination of the defined context classes (C0 – C6).

9. A method according to any of the Claim 1 to 8, **characterized** in that in the method a cost function is defined, wherein the selection of the prediction method comprises the steps of:

- calclulating a value of the cost function for at least two prediction methods,
- exploring the calculated cost function values to finding the minimum value, and
- selecting the prediction method which produces said minimum value for the cost function.

10. A method according to Claim 9, **characterized** in that the cost function is defined as

$$Cx = D + \lambda R,$$

where cost Cx is defined as a weighted sum of distortion D and rate R associated with each of the prediction methods and λ is the weighting factor.

11. A method according to any of the Claim 1 to 10, **characterized** in that in the method a prediction error is defined on the basis of the predicted block and the real pixel values of said block (C), and that the prediction error information is coded, and the coded prediction error information is transmitted.

12. A device for transmitting frames, which have been formed from digital images, and the frames are divided into blocks (C, L, U, UL, UR), **characterized** in that the device comprises means for performing spatial prediction for a block (C) to reduce the amount of information to

be transmitted, wherein at least one prediction method (P1—P13) has been defined, that the device further comprises means for determining a classification for at least one neighbouring block (L, U) of said block (C) to be predicted according to the contents of said neighbouring block (L, U), and means for selecting a prediction method (P1—P13) for the current block (C) on the basis of at least one said classification.

13. A device according to Claim 12, **characterized** in that the means for determining classification comprises means for determining directionality information of the block.

14. A device according to Claim 13, **characterized** in that the means for determining directionality information comprises means for calculating at lest one gradient value (g_k) on the basis of pixel values of said block.

15. A device according to Claim 14, **characterized** in that the gradient values (g_k) have been calculated with the following formula

$$
\begin{aligned}
g_0 &= \frac{1}{N(N-1)} \max\left(1, \sum_{y=0}^{N-1}\sum_{x=0}^{N-2} \left|I(x,y) - I(x+1,y)\right|\right) \\
g_1 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2}\sum_{x=1}^{N-1} \left|I(x,y) - \tfrac{1}{2}\left(I(x-1,y) + I(x-1,y+1)\right)\right|\right) \\
g_2 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2}\sum_{x=1}^{N-1} \left|I(x,y) - I(x-1,y+1)\right|\right) \\
g_3 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2}\sum_{x=1}^{N-1} \left|I(x,y) - \tfrac{1}{2}\left(I(x-1,y+1) + I(x,y+1)\right)\right|\right) \\
g_4 &= \frac{1}{N(N-1)} \max\left(1, \sum_{y=0}^{N-2}\sum_{x=0}^{N-1} \left|I(x,y) - I(x,y+1)\right|\right) \\
g_5 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2}\sum_{x=0}^{N-2} \left|I(x,y) - \tfrac{1}{2}\left(I(x,y+1) + I(x+1,y+1)\right)\right|\right) \\
g_6 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2}\sum_{x=0}^{N-2} \left|I(x,y) - I(x+1,y+1)\right|\right) \\
g_7 &= \frac{1}{(N-1)^2} \max\left(1, \sum_{y=0}^{N-2}\sum_{x=0}^{N-2} \left|I(x,y) - \tfrac{1}{2}\left(I(x+1,y) + I(x+1,y+1)\right)\right|\right)
\end{aligned}
\quad (1)
$$

where N is the size of the block, I(x,y) represent the pixel intensity values, indices x and y refer to coordinates of pixel inside the block, and k represents edge orientations.

16. A device according to Claim 15, **characterized** in that at least eight directionality classes (D0 – D7) have been defined for different edge orientations.

17. A device according to any of the Claim 12 to 16, **characterized** in that the classification comprises further 3 non-directional classes (D8 – D10) corresponding to flat, smooth texture and coarse texture blocks.

18. A device according to any of the Claim 12 to 17, **characterized** in that at least two context classes (C0 – C6) have been defined, therein the device comprises means for performing a mapping phase, in which the classification information (D8 – D10) is arranged to be mapped into one of said context classes (C0 – C6).

19. A device according to any of the Claim 12 to 18, **characterized** in that the device comprises means for performing classification for two neighbouring blocks (L, U) of said block (C) to be predicted according to the contents of said neighbouring blocks (L, U), means for defining context classes (C0 – C6) for said neighbouring blocks (L, U), and means for selecting a prediction method (P1—P13) for the current block (C) on the basis of a combination of the defined context classes (C0 – C6).

20. A device according to any of the Claim 12 to 19, **characterized** in that a cost function has been defined, wherein means for selecting a prediction method (P1—P13) comprises means for:

- calclulating a value of the cost function for at least two prediction methods,
- exploring the calculated cost function values to finding the minimum value, and
- selecting the prediction method which produces said minimum value for the cost function.

21. A method according to Claim 20, **characterized** in that the cost function has been defined as

$$Cx = D + \lambda R,$$

where cost Cx has been defined as a weighted sum of distortion D and rate R associated with each of the prediction methods and λ is the weighting factor.

22. A device according to any of the Claim 12 to 21, **characterized** in that the device comprises means for defining a prediction error on the basis of the predicted block and the real pixel values of said block (C), means for coding the prediction error information, and means for transmitting the coded prediction error information.

23. An encoder (1) comprising means for forming frames from digital images, and means for dividing the frames into blocks (C, L, U, UL, UR), **characterized** in that the encoder (1) comprises means for

performing spatial prediction for a block (C) to reduce the amount of information to be transmitted, wherein at least one prediction method (P1—P13) has been defined, that the encoder (1) further comprises means for determining a classification for at least one neighbouring block (L, U) of said block (C) to be predicted according to the contents of said neighbouring block (L, U), and means for selecting a prediction method (P1—P13) for the current block (C) on the basis of at least one said classification.

24. A decoder (10) comprising means for receiving frames, which have been formed from digital images, and the frames are divided into blocks (C, L, U, UL, UR), **characterized** in that the decoder (10) comprises means for performing spatial prediction for a block (C) to reduce the amount of information to be transmitted, wherein at least one prediction method (P1—P13) has been defined, that the decoder (10) further comprises means for determining a classification for at least one neighbouring block (L, U) of said block (C) to be predicted according to the contents of said neighbouring block (L, U), and means for selecting a prediction method (P1—P13) for the current block (C) on the basis of at least one said classification.

25. A codec (1, 10) comprising means for forming frames from digital images, means for dividing the frames into blocks (C, L, U, UL, UR), and means for receiving frames, **characterized** in that the codec (1, 10) comprises means for performing spatial prediction for a block (C) to reduce the amount of information to be transmitted, wherein at least one prediction method (P1—P13) has been defined, that the codec (1, 10) further comprises means for determining a classification for at least one neighbouring block (L, U) of said block (C) to be predicted according to the contents of said neighbouring block (L, U), and means for selecting a prediction method (P1—P13) for the current block (C) on the basis of at least one said classification.

26. A mobile terminal (24) comprising means for forming frames from digital images, means for dividing the frames into blocks (C, L, U, UL, UR), and means for receiving frames, **characterized** in that the mobile terminal (24) comprises means for performing spatial prediction for a block (C) to reduce the amount of information to be transmitted, wherein at least one prediction method (P1—P13) has been defined,

that the mobile terminal (24) further comprises means for determining a classification for at least one neighbouring block (L, U) of said block (C) to be predicted according to the contents of said neighbouring block (L, U), and means for selecting a prediction method (P1—P13) for the current block (C) on the basis of at least one said classification.

27. A storage media for storing a software program comprising machine executable steps for forming frames from digital images, and for dividing the frames into blocks (C, L, U, UL, UR), **characterized** in that the software program further comprises machine executable steps for performing spatial prediction for a block (C) to reduce the amount of information to be transmitted, wherein at least one prediction method (P1—P13) has been defined, steps for determining a classification for at least one neighbouring block (L, U) of said block (C) to be predicted according to the contents of said neighbouring block (L, U), and steps for selecting a prediction method (P1—P13) for the current block (C) on the basis of at least one said classification.

Abstract:

The invention relates to a method for transmitting digital images, in which method at least one frame is formed from the digital image, and the frame is divided into blocks (C, L, U, UL, UR). In the method a spatial prediction for a block (C) is performed to reduce the amount of information to be transmitted, wherein at least one prediction method (P1—P13) is defined. In the method a classification is determined for at least one neighbouring block (L, U) of said block (C) to be predicted according to the contents of said neighbouring block (L, U), and a prediction method (P1—P13) is selected for the current block (C) on the basis of at least one said classification.

Fig. 2

42

1/1

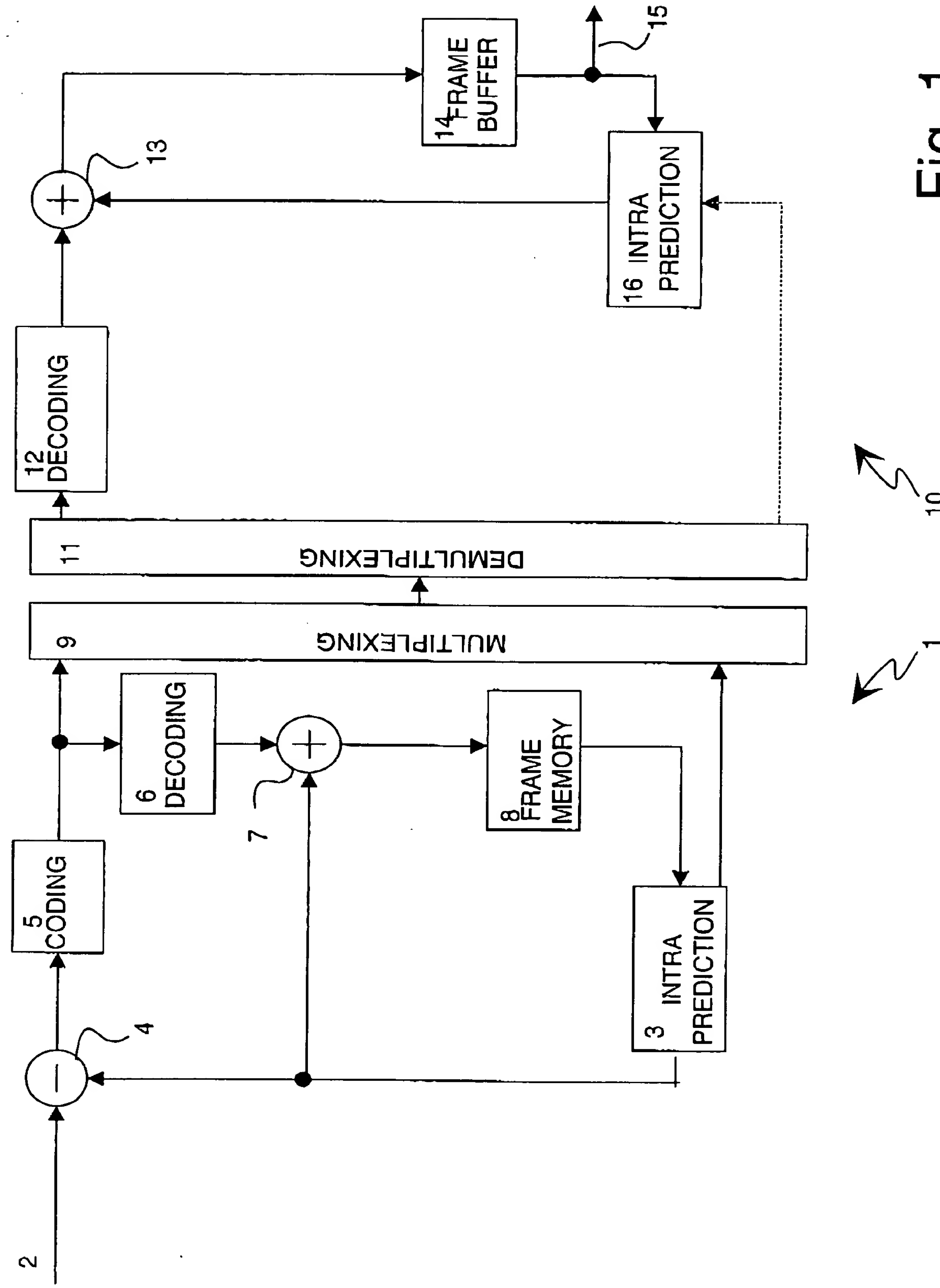
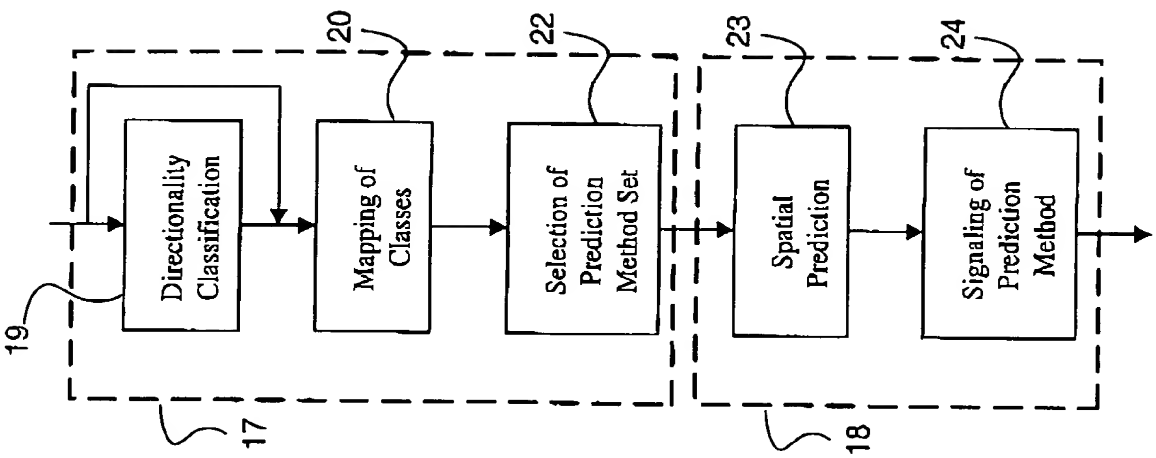

2
4
5 CODING
6 DECODING
7
8 FRAME MEMORY
3 INTRA PREDICTION
9 MULTIPLEXING
1
11 DEMULTIPLEXING
10
12 DECODING
13
14 FRAME BUFFER
15
16 INTRA PREDICTION

Fig. 1

Fig. 2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Mapping of Classes
Selection of Prediction Method Set
Spatial Prediction
Signaling of Prediction Method
17
18
19
20
22
23
24

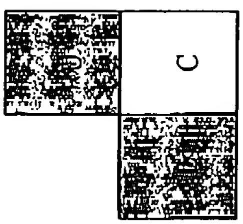

Fig. 3a

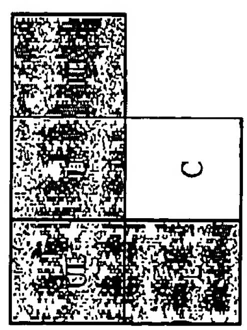

Fig. 3b

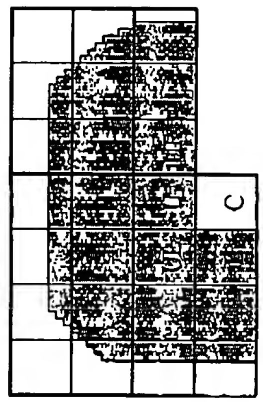

Fig. 3c

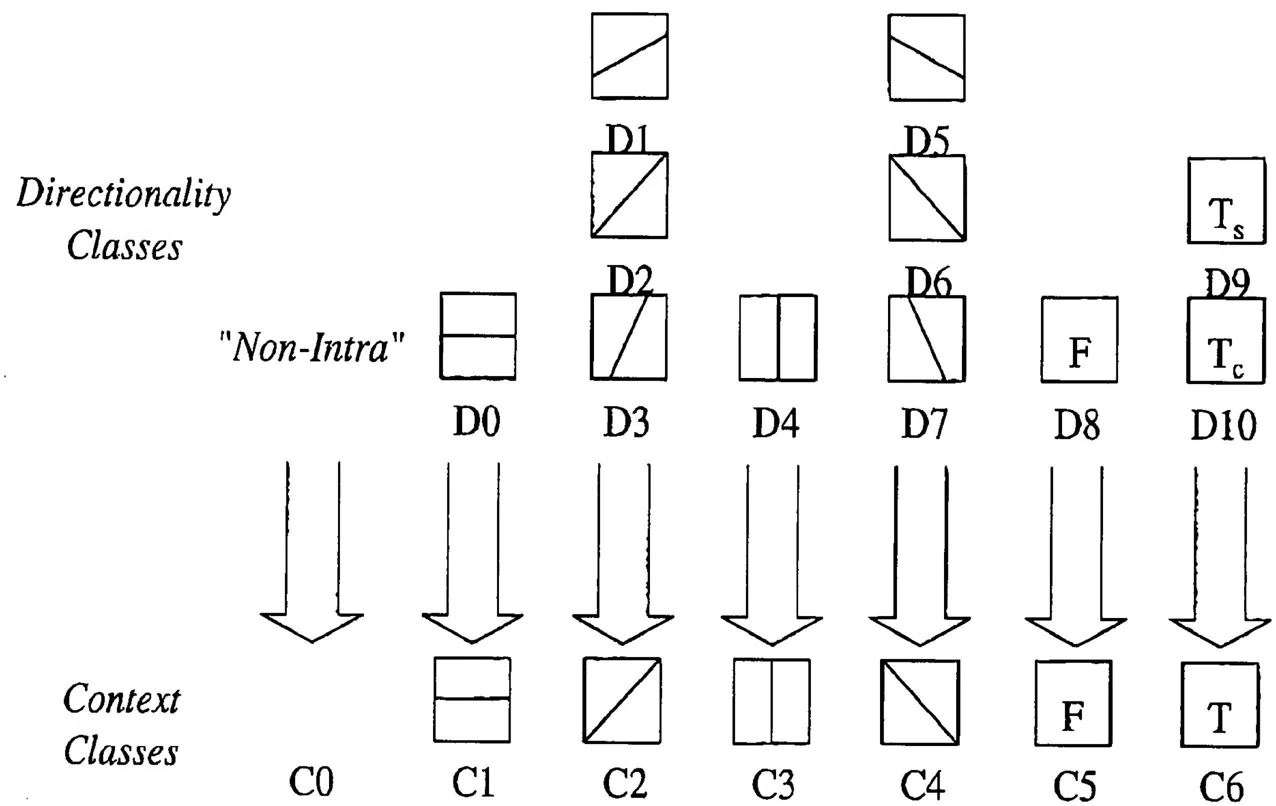
Directionality Classes
"Non-Intra"
D1
D5
D2
D6
D9
F
Ts
Tc
D0
D3
D4
D7
D8
D10
Context Classes
F
T
C0
C1
C2
C3
C4
C5
C6

Fig. 4

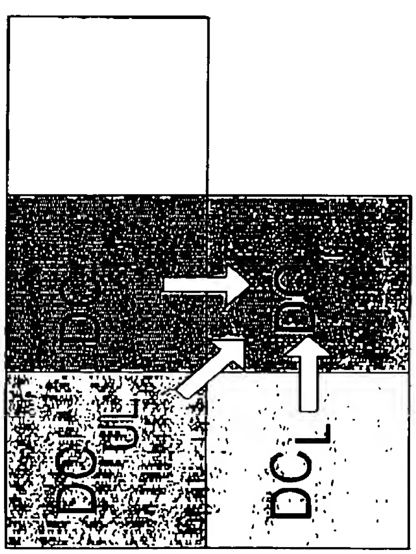

Fig. 5a

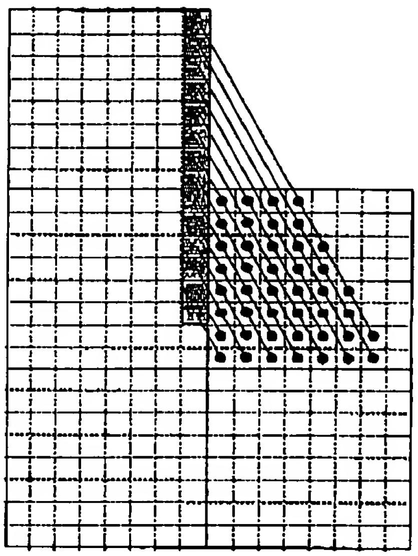

Fig. 5b

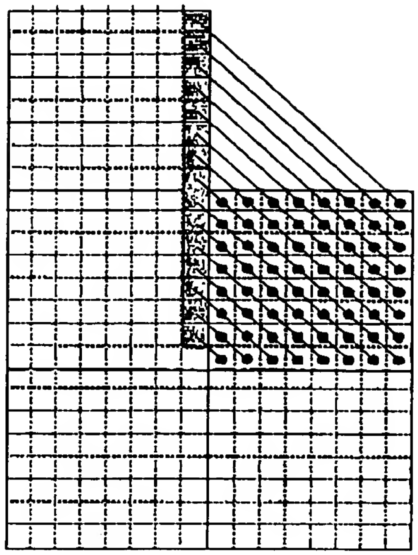

Fig. 5c

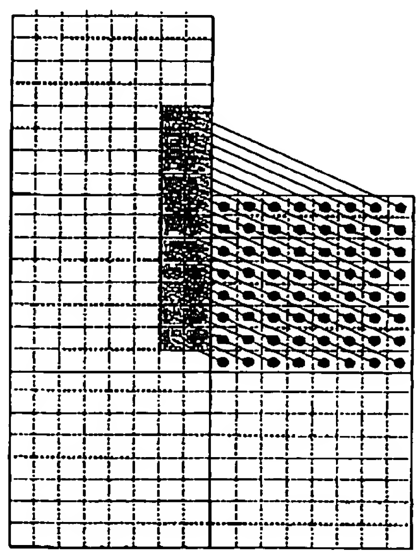

Fig. 5d

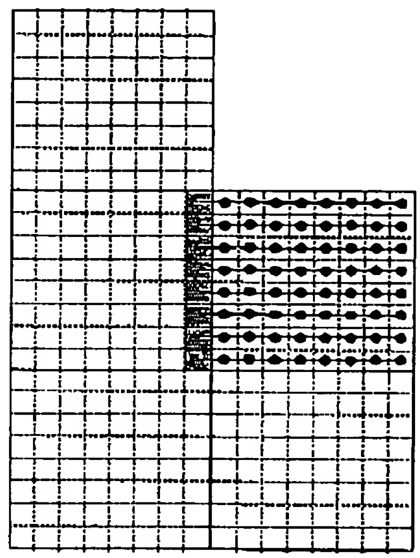

Fig. 5e

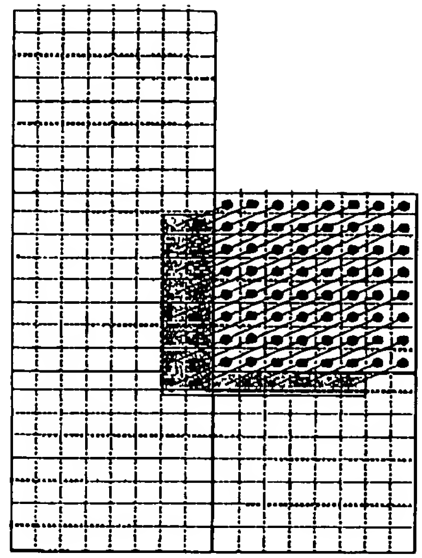

Fig. 5f

b

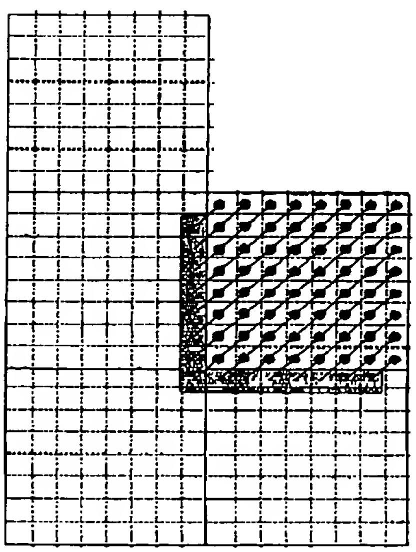

Fig. 5g

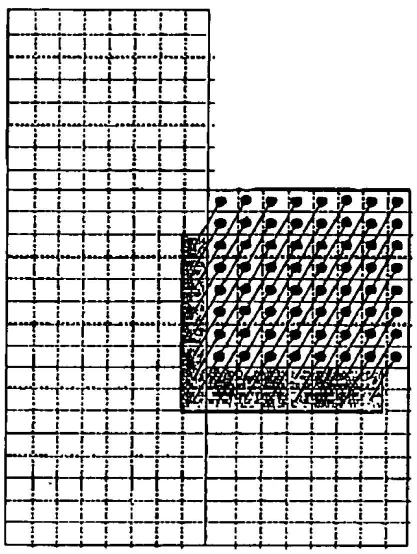

Fig. 5h

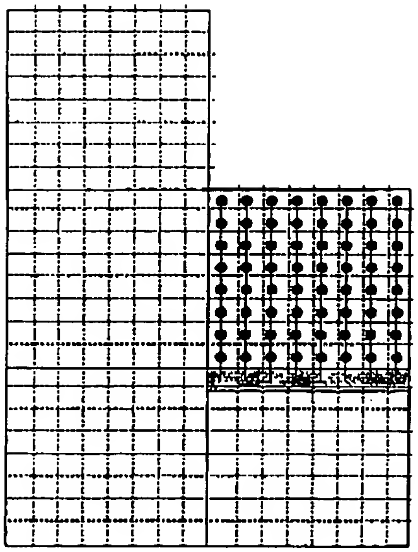

Fig. 5i

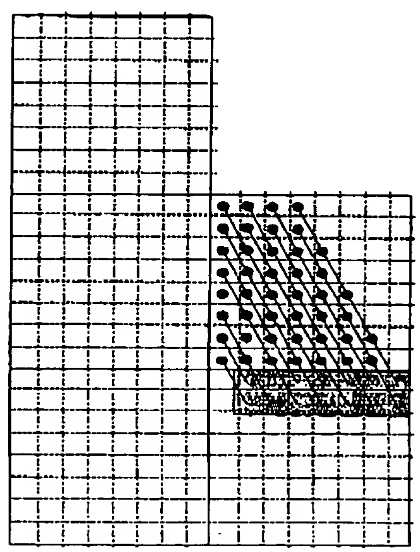

Fig. 5j

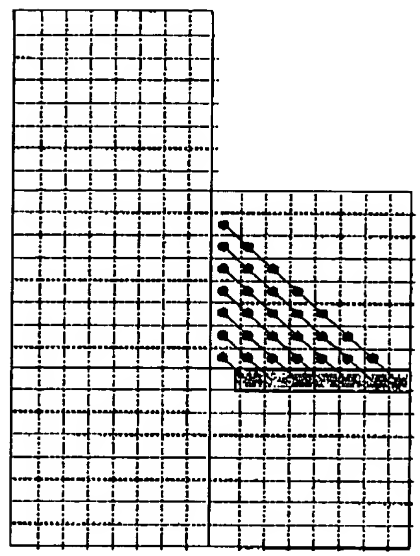

Fig. 5k

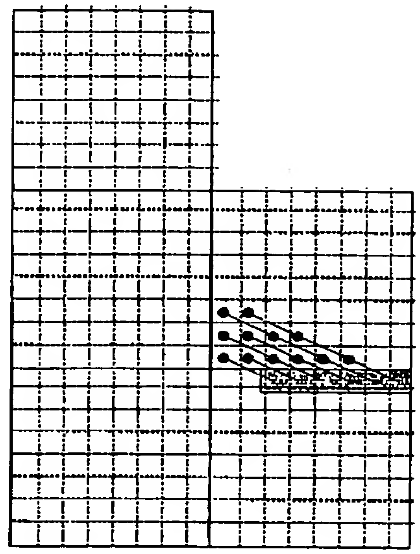

Fig. 5l

7

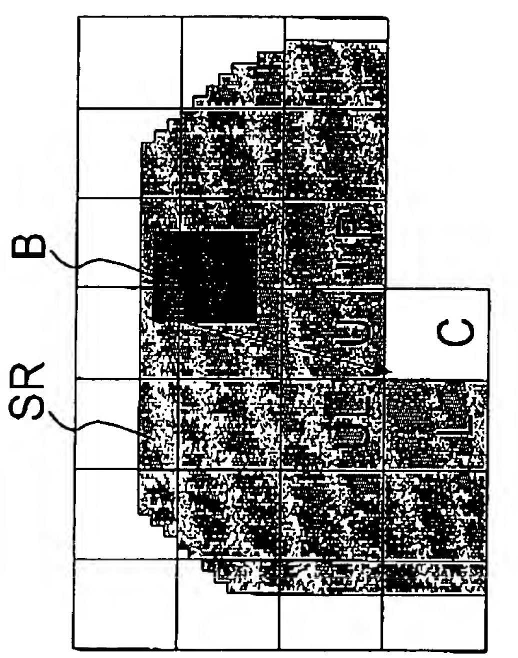

Fig. 5m

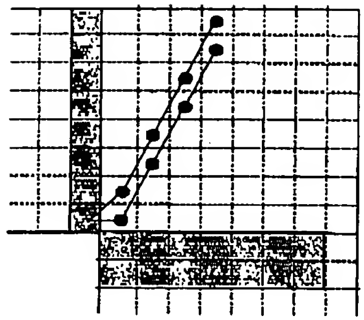

Fig. 5p

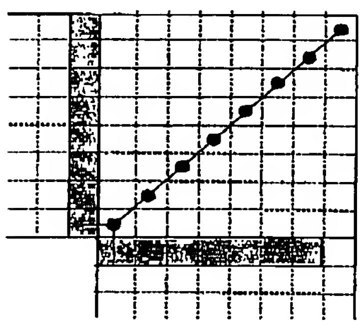

Fig. 5o

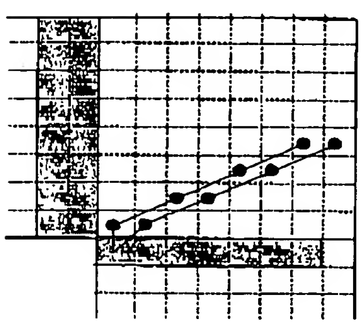

Fig. 5n

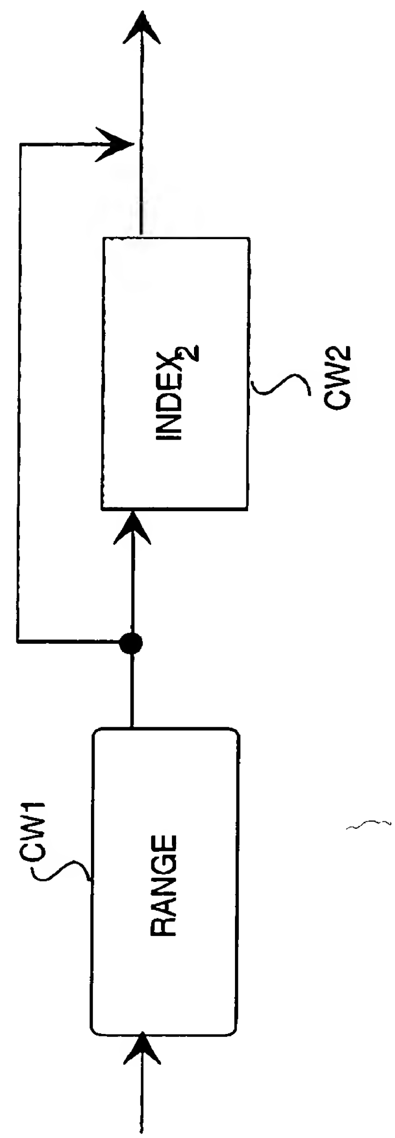

Fig. 6

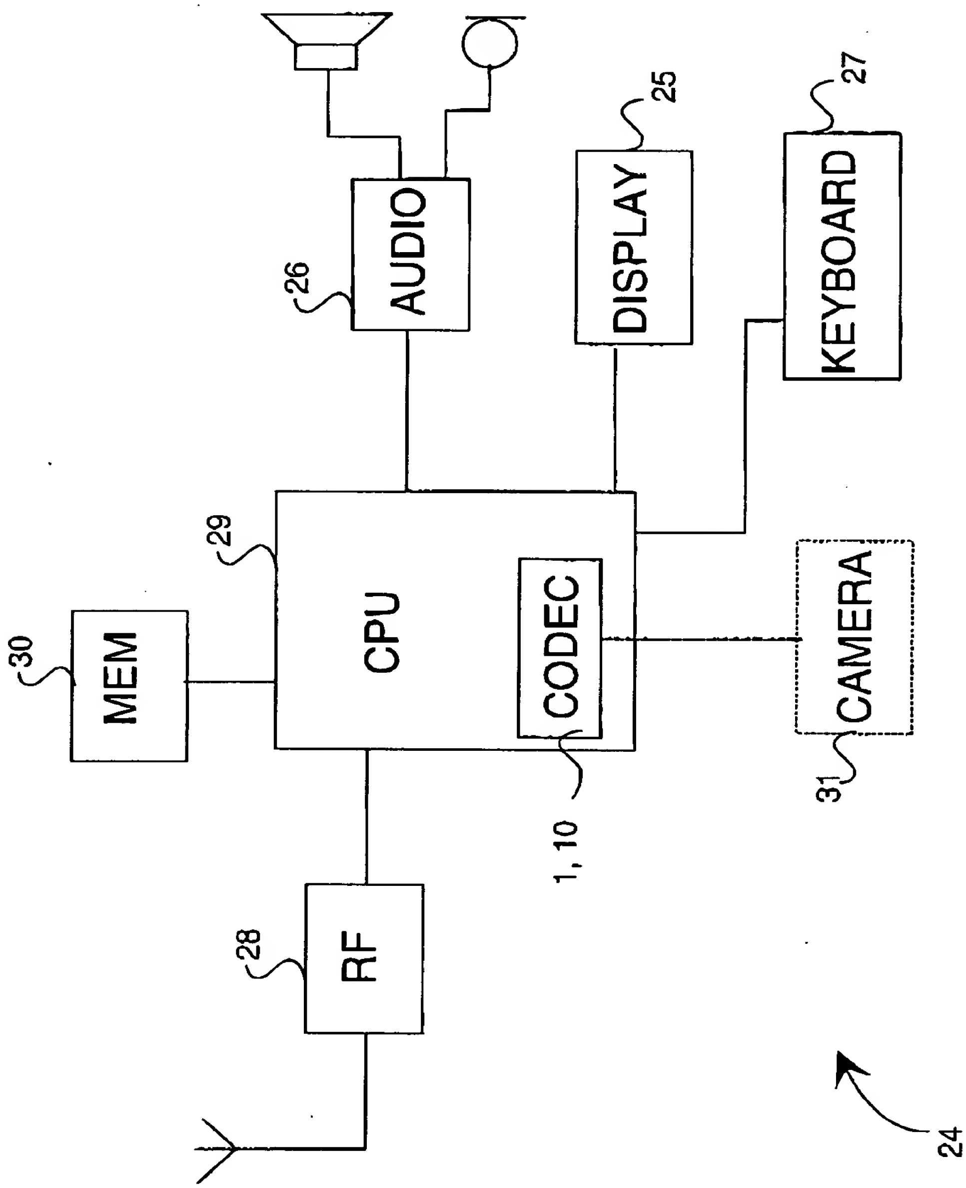
AUDIO
26
DISPLAY
25
KEYBOARD
27
CPU
29
CODEC
1, 10
CAMERA
31
MEM
30
RF
28
24

Fig. 7